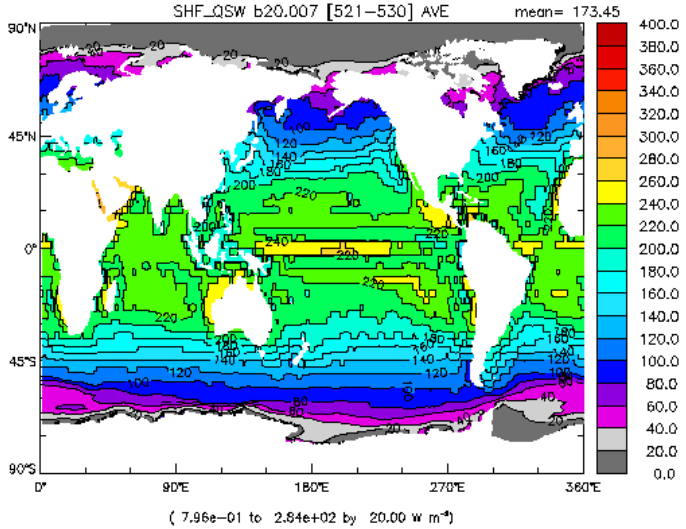
U.S. IOOS Coastal Ocean Modeling Testbed (COMT) Support for Scenario-based Ecological Forecasts

Marjorie Friedrichs
Virginia Institute of Marine Science

U.S. IOOS “Modeling and Analysis” Subsystem

The U.S. IOOS Program’s role in terms of “Modeling and Analysis” is to:

- Simplify access to data to support models
- Simplify access to model outputs
- Help match customer needs to existing models
- Assist with prototyping and testing of models



→ The Coastal Ocean Modeling Testbed (COMT)

COMT Ongoing Goals

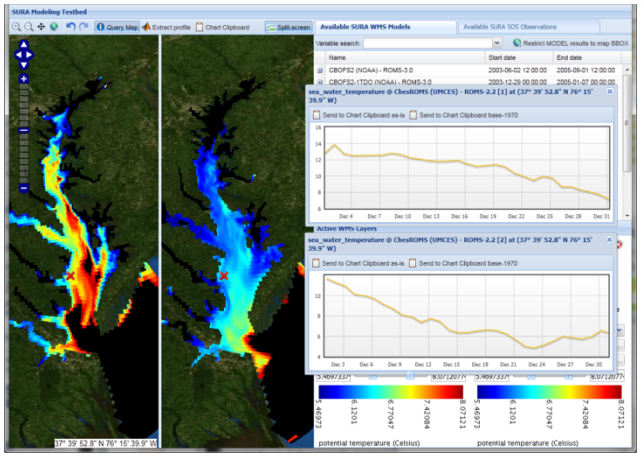
1. Advance common infrastructure for access, analysis and visualization of all ocean model output produced by the Federal Backbone and the IOOS Regions

2. Improve R2O and O2R by building stronger relationships between academia and operational centers through collaboration

3. Advance skill metrics and assess models in different regions and dynamic regimes

4. Transition models, tools, toolkits and other capabilities to academic research centers to federal operational facilities

COMT Background



Unique Elements:

- Intended to be inter-agency
- Managed by a non-federal partner
- Multi-sector engagement
  (federal, academia, industry)

Composition:

- SURA = non-federal partner; lead for execution
- Phase 1: 2010-2012
  3 science teams + cyber-infrastructure
- Phase 2: 2013-2015
  4 science teams + cyber-infrastructure

Current COMT

Goal: To improve understanding and operational forecasts of extreme events and chronic environmental conditions affecting the U.S.

Five Teams:

1) Chesapeake Bay Estuarine Hypoxia Forecasting
2) Integration of West Coast Operational Coastal & Ocean Models
3) Puerto Rico/US Virgin Islands Inundation & Wave Forecasting
4) Northern Gulf of Mexico Ecological Forecasting
5) Cyberinfrastructure

Current COMT

Goal: To improve understanding and operational forecasts of extreme events and chronic environmental conditions affecting the U.S.

Five Teams:

1) Chesapeake Bay Estuarine Hypoxia Forecasting

VIMS: Marjy Friedrichs (lead PI)
Carl Friedrichs (VIMS-PI)
Ike Irby (funded student)
Aaron Bever (consultant)
Jian Shen (collaborator)
Cathy Feng (collaborator)

WHOI: Malcolm Scully (WHOI-PI)

UMCES: Raleigh Hood (UMCES-PI)
Hao Wang (funded student)
Jeremy Testa (collaborator)
Wen Long (collaborator)

NOAA-CSDL: Lyon Lanerolle (NOAA-PI)
Frank Aikman (collaborator)

Chesapeake Hypoxia Objective

Assess the readiness and maturity of a suite of existing estuarine ecological community models for determining past, present and future hypoxia events within the Chesapeake Bay, in order to **accelerate the transition of hypoxia model formulations and products from "academic research" to "operational" centers**

Chesapeake Hypoxia COMT "operational" centers include:

- Chesapeake Bay Ecological Prediction System (CBEPS)
  - Short-term forecasts (R. Hood)
- NOAA/NOS/CO-OPS
  - Short-term forecasts (L. Lanerolle)
- EPA Chesapeake Bay Program (CBP)
  - Scenario-based forecasts (M. Friedrichs, C. Friedrichs, I. Irby)

Chesapeake Hypoxia Model Comparisons

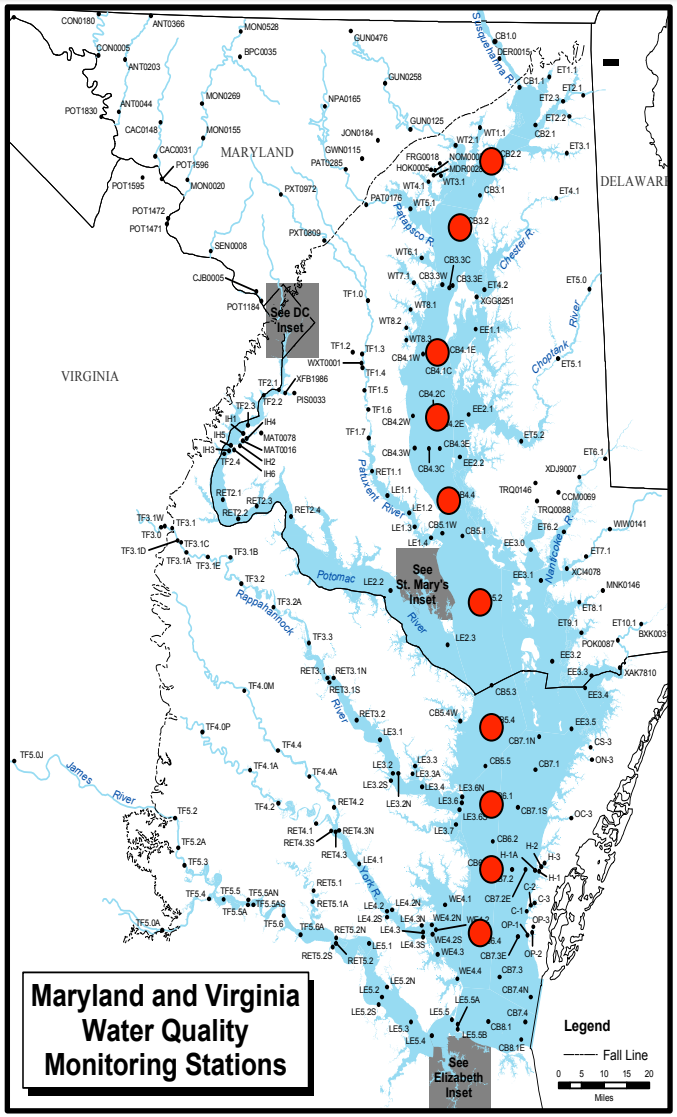
To assess the readiness and maturity of our suite of Chesapeake hypoxia models, we are:

- Statistically comparing output from four Chesapeake Bay models:
  - three ROMS models; varying biological complexity; similar forcing (ChesNENA, ChesROMS-BGC, ROMS-RCA)
  - biologically sophisticated CBP regulatory/operational model (CH3D-ICM)

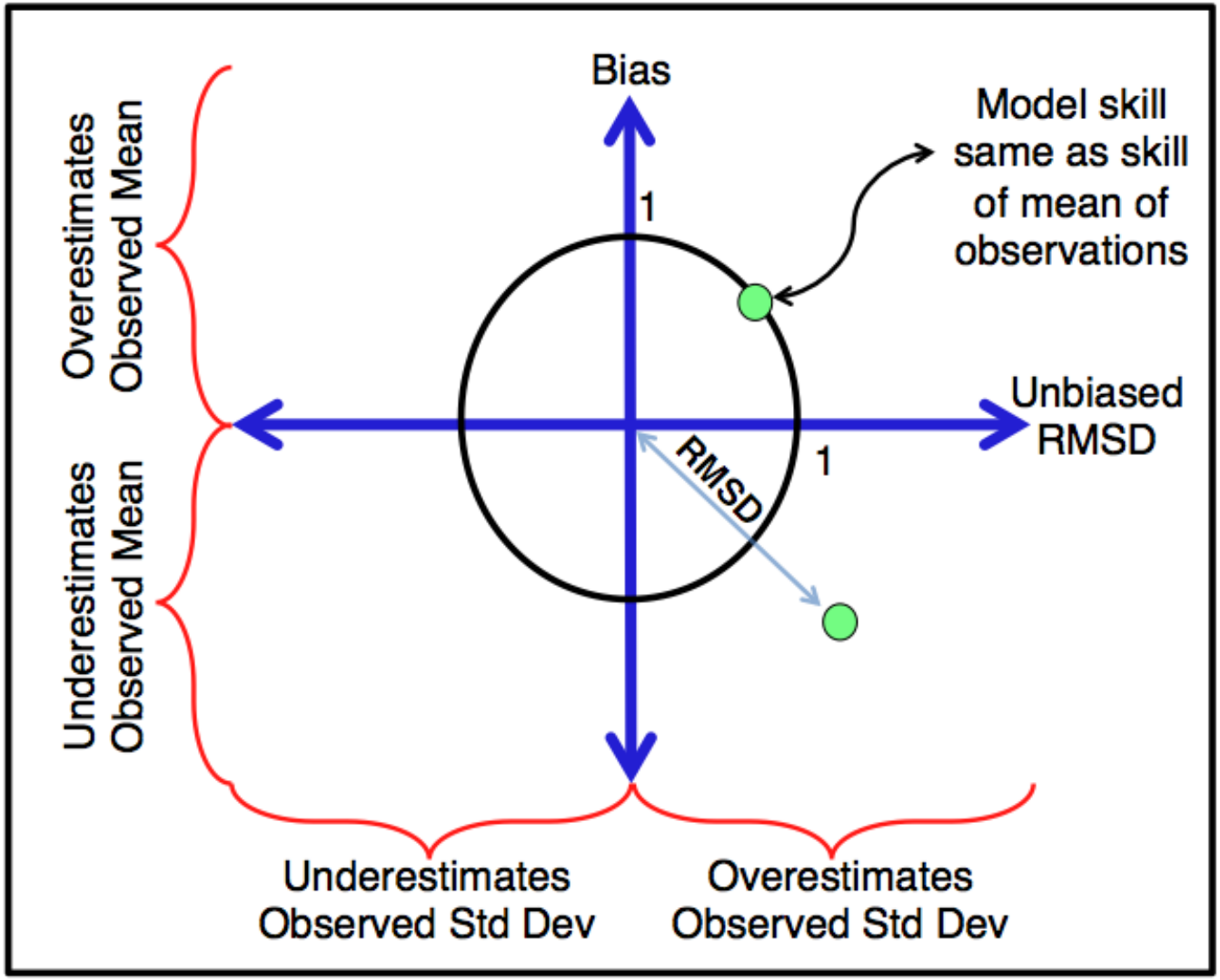
- Examining how well they reproduce the mean and spatial/seasonal variability of:
  - temperature, salinity, stratification, dissolved oxygen (DO), chlorophyll-a, and nitrate

Chesapeake Hypoxia Model Comparisons

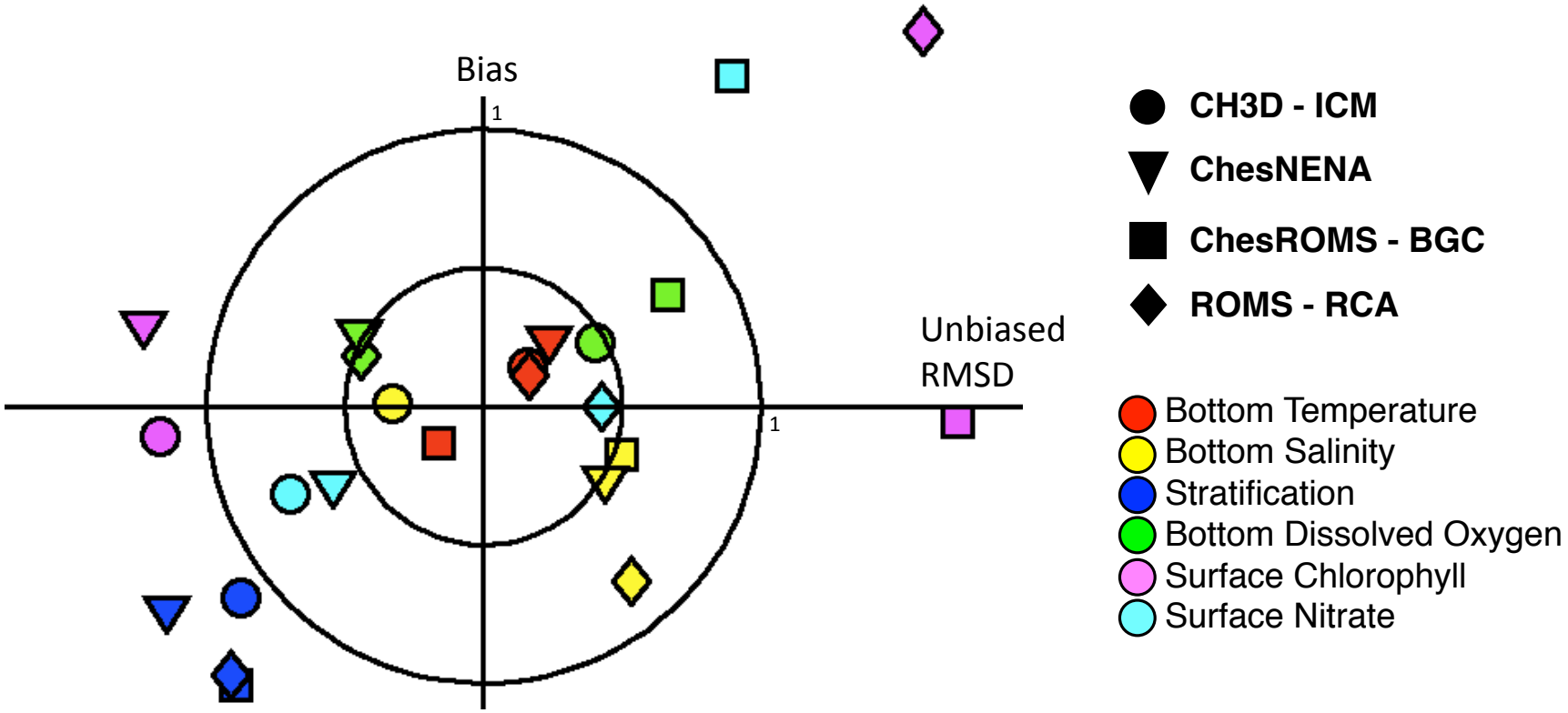
Compare simulations to observations at 10 main stem stations for ~16 cruises in 2004 and 2005



Model Skill Assessment via Target Diagrams



Model Comparison Results



Overall skill of all four models (temporal + spatial variability) are:

- **highest** in terms of **Temperature**
- **similar** to each other in terms of **T, S, stratification** and **DO**
- **different** in terms of **chlorophyll** and **nitrate**

Model Comparison Summary

- Regardless of complexity, models do similarly well in terms of reproducing observations of T, S and DO, and similarly poorly in terms stratification
- All models reproduce DO better than variables that are typically thought to be primary influences on DO (stratification, chlorophyll, nitrate)
  - This is because seasonal DO variability is sensitive to T (solubility effect), and the models reproduce T very well
  - Modeled DO simulations may be very sensitive to any future increases in Bay temperature

→ Hypoxia forecasting is possible with simple biological formulations

Chesapeake Hypoxia "Forecasts"

Use information from multiple model comparisons to improve "operational" hypoxia forecasts:

1. **CBEPS short-term forecasting:** by developing a 24/7 predictive capacity for nowcasting/forecasting of oxygen/hypoxic volume (and other biogeochemical variables) using multiple models, as part of CBEPS at UMCES

2. **CBOFS short-term forecasting:** by incorporating new oxygen and physical model enhancements into the existing operational NOAA CO-OPS Chesapeake Bay Operational Forecast System (CBOFS) for evaluation during their next update

3. **CBP scenario-based forecasting:** Apply the official CBP nutrient reduction strategies to COMT models to determine whether they perform similarly to the regulatory/operational CBP model in terms of predicting the effect of reduced nutrients on hypoxia

Breakout session questions

- What is a definition of operational for the COMT models?

  "*A modeling system that regularly produces hindcasts/nowcasts/forecasts that contribute to satisfying a management or service need, ideally with uncertainty estimates*"

  → CBEPS (operational short-term forecasts at UMCES)

  → CBOFS (truly operational, short-term forecasts)

  → EPA-CBP (operational scenario-based forecasts)

- What is required for a model to become operational?

  In the R&D phase of operational ecosystem model development, multiple models are critical

  → hindcasting – comparison of hindcasts highlights models with greatest skill, identifies errors in models

  → forecasting – comparison of forecasts provides uncertainty estimates

Breakout session questions

- What does it take to keep a model operational and what could the federal government provide for these types of forecasts?

→ Funding for resources such as people, clusters, data sources…

→ Regular improvement/updates to the models

- Operational models must incorporate research advances

Testbeds can assist with linking operational and research facilities

Extra slides

Ecological Forecasting Roadmap

NOAA's Ecological Forecasting Roadmap is a plan to deliver coordinated, accurate, and resource-efficient ecological forecast products.

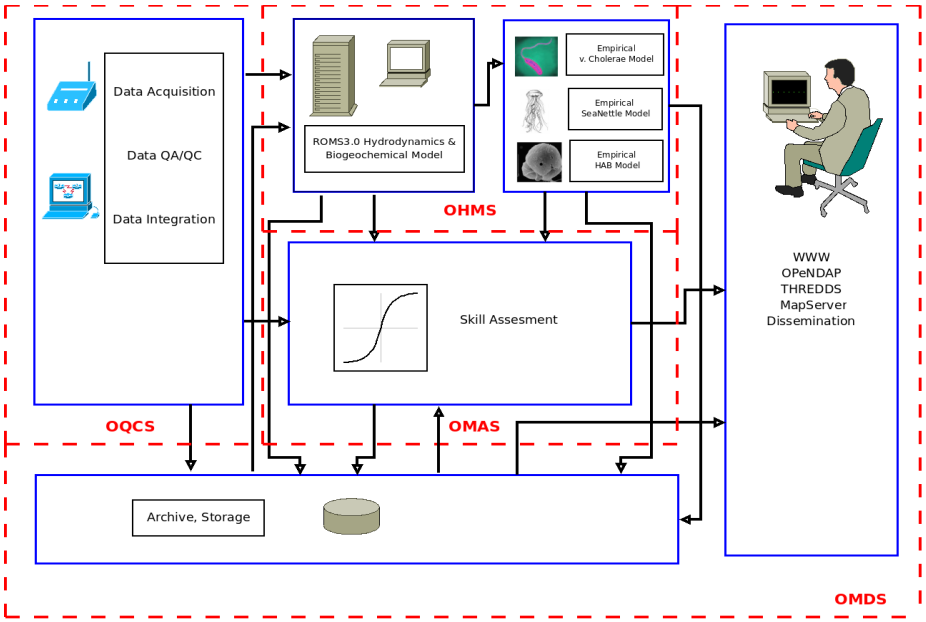
- From Roadmap Site: http://oceanservice.noaa.gov/ecoforecasting

- One of the four EF Roadmap teams is "hypoxia", originally focused on Gulf of Mexico, but now expanding to include Chesapeake Bay

→ **The Coastal Ocean Modeling Testbed (COMT)**

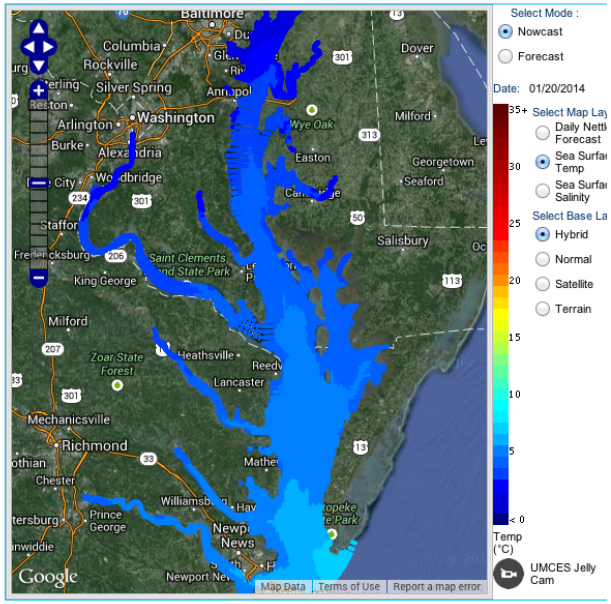
Chesapeake Bay Ecological Prediction System (CBEPS)

- Coupled hydrodynamic/biogeochemical model (ChesROMS) running “operationally” at UMCES (formally supported by NOAA/NCBO)
- Nowcasts: real time USGS river discharge; Forecasts: assume river flows persist for 3 days
- Atmospheric forcing for 3-day forecasts from the N. American Meteorological Model
- Simple seasonal climatologies/flow for biogeochemical boundary conditions
- Baywide nowcasts & 3 day forecasts of T and S are generated daily & posted
- Baywide ecological nowcasts & 3 day forecasts of Sea Nettles and Vibrio are generated daily, based on T, S logistical regression models (Vibrio not posted)

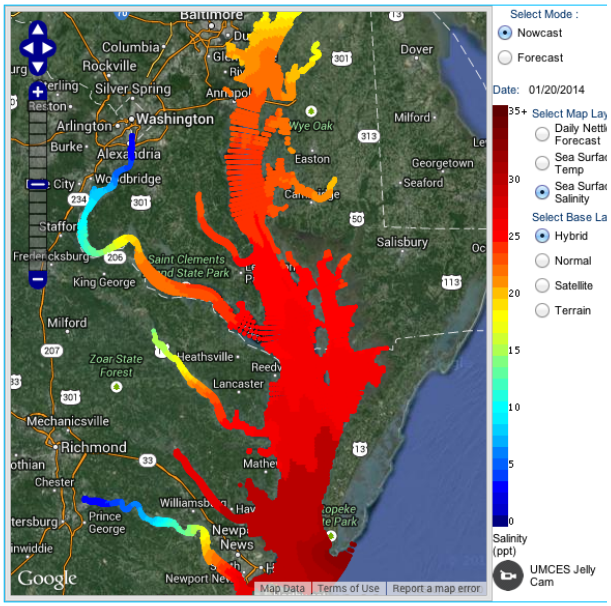


Chesapeake Bay Ecological Prediction System (CBEPS)

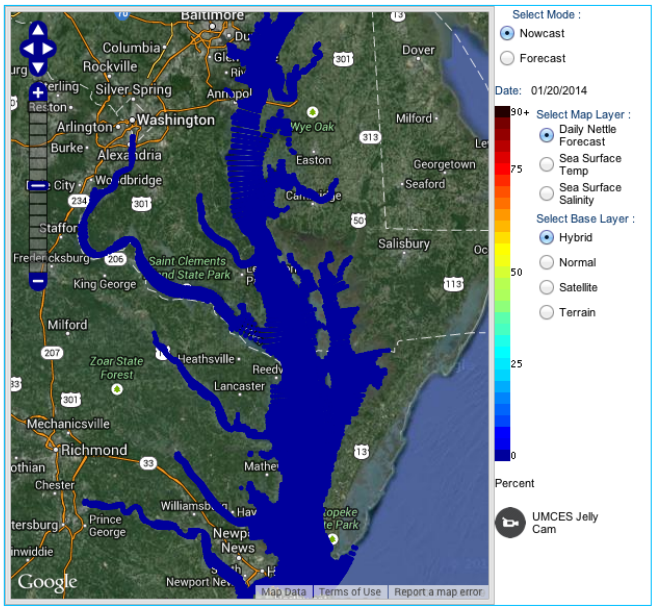
Nowcasts/forecasts generated daily and posted on website



Surface Temperature



Surface Salinity



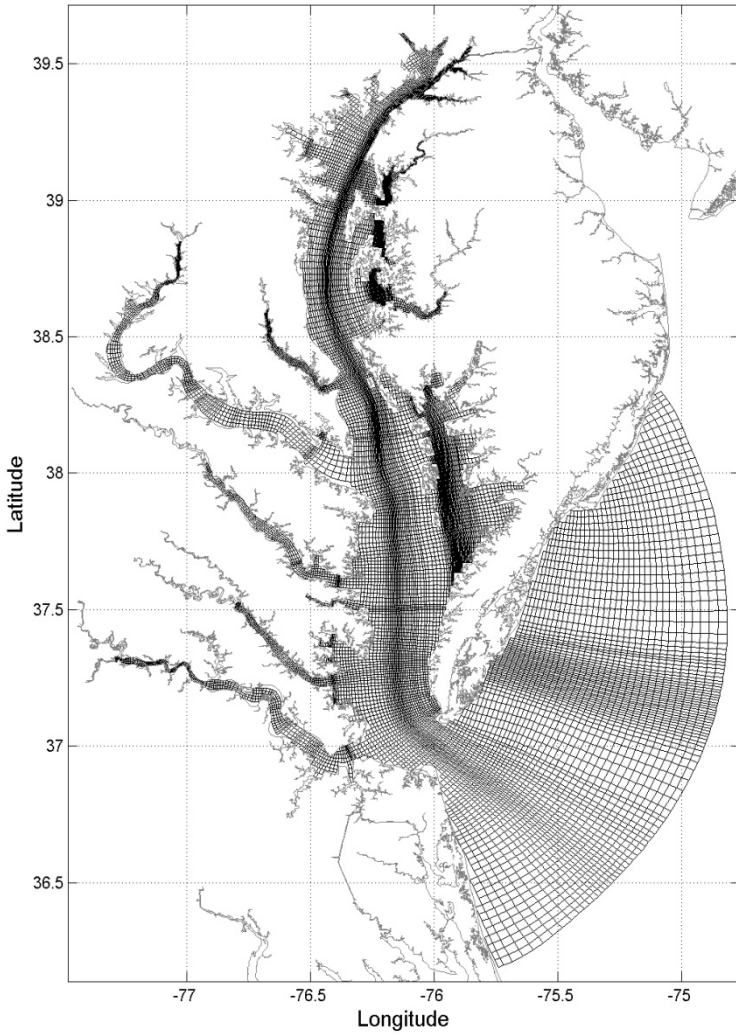
Sea Nettles

20 Jan 2014

CBOFS

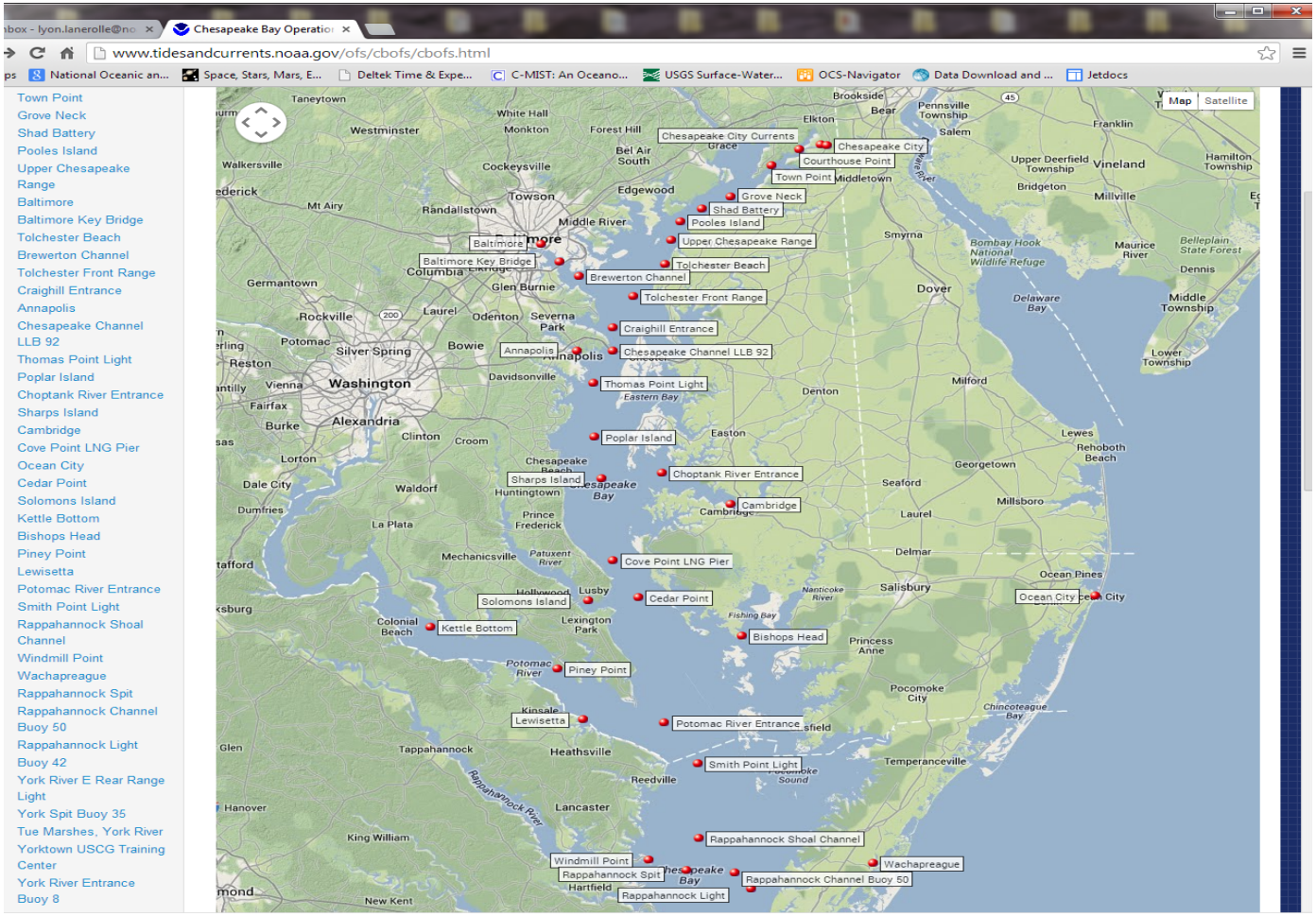
- CBOFS based on Regional Ocean Modeling System (ROMS)
- Grid generated in segments and pasted seamlessly using Delft3D-RGFGRID generator
- Bathymetry: NOS soundings cut-off at 2m depth
- Init Conds: NOAA T, S climatology for lower Bay and CBP profiles for upper Bay
- Rivers: discharge = USGS; T, S = CBP
- Outer Bdy Conds: T, S = NOAA climatology
- Outer Bdy Tides: tidal harmonic constituents for WL and barotropic currents from ADCIRC database
- No sediment, precipitation, wetting/drying or data assimilation

CBOFS Model Grid



CBOFS Model Archive Sites

Archive water elevations, currents, T and S at all of the above locations, but not yet dissolved oxygen



CBOFS model output